5 Marks question

Module 1:

1. Compare Micro grid with conventional utility grid
2. (i) What is Micro grid?
   (ii) List its characteristics
3. Explain the concept of Distributed Energy Resources (DERs).
4. (i) What are conventional and non-conventional energy source?
   (ii) What are the advantages and disadvantages of conventional & non-conventional energy source?
5. Explain the importance of non-conventional energy sources in the present context?

1. Explain the evolution of power systems from traditional methods to modern practices. What are the key factors that have influenced this evolution? CO1

Hint: The evolution of power systems has progressed from isolated systems powered by local generators to interconnected bulk power grids and microgrids. Key factors influencing this evolution include advancements in technology, increasing energy demand, the need for reliability, environmental concerns prompting the use of renewable energy sources, and regulatory changes encouraging competition and efficiency in the power sector.

2. **Differentiate between bulk power grids and microgrids in terms of structure and operational characteristics. CO2**

Hint: Bulk power grids consist of large-scale generation sources and extensive transmission networks, serving vast geographic areas with high voltage levels. They are designed for centralized control and reliability. In contrast, microgrids are smaller, localized systems that can operate independently or in conjunction with the bulk grid. They typically incorporate distributed energy resources, offer greater flexibility, and enhance resilience to outages.

3. **Describe the different types of conventional and renewable energy sources used for electricity generation. Provide examples of each. CO1**

Hint: Conventional energy sources include fossil fuels (coal, natural gas, and oil) and nuclear power, which have been the primary means of generation for decades. Renewable energy sources include solar (photovoltaic and thermal), wind, hydroelectric, biomass, and geothermal. For example, coal-fired power plants represent conventional sources, while solar farms and wind turbines exemplify renewable sources.

4. **Discuss the role of energy storage systems in modern power systems. What are the main types of energy storage technologies? CO2**

Hint: Energy storage systems play a critical role in enhancing the reliability and flexibility of power systems, particularly with the integration of intermittent renewable energy sources. They help balance supply and demand, improve grid stability, and provide backup

during outages. Main types of energy storage technologies include battery storage (lithium-ion, lead-acid), pumped hydro storage, flywheels, and compressed air energy storage.

5. **Explain the significance of transmission and distribution systems in power systems. How do line diagrams and voltage levels differ in meshed and radial topologies? CO2**

Hint: Transmission and distribution systems are crucial for transporting electricity from generation sources to end-users. Transmission lines operate at high voltages to minimize losses over long distances, while distribution networks deliver power at lower voltages to homes and businesses. In meshed topologies, multiple interconnections enhance reliability and redundancy, allowing for multiple paths for power flow. In radial topologies, power flows from a single source to several branches, which can lead to outages if a single line fails, as there are no alternative paths.

6. **Analyze the impact of distributed energy resources (DERs) on the traditional power system. Discuss the challenges and benefits associated with their integration. CO4**

Hint: Distributed energy resources, such as solar panels, wind turbines, and energy storage systems, significantly impact the traditional power system by decentralizing generation and enhancing grid resilience. Benefits include reduced transmission losses, increased reliability, and the ability to meet local demand. However, challenges include maintaining grid stability, managing variability and intermittency of renewable sources, and the need for upgraded grid infrastructure to accommodate bidirectional power flows and advanced control systems.

7. **Compare and contrast the operational characteristics and advantages of bulk power grids and microgrids in modern power systems. How do they contribute to grid resilience? CO4**

Hint: Bulk power grids operate at a large scale, connecting multiple generation sources with extensive transmission networks. They provide economies of scale and reliable power supply across vast regions. In contrast, microgrids are localized systems that can operate independently or connect to the main grid, allowing for localized generation and load management. Microgrids enhance grid resilience by providing backup power during outages and integrating renewable sources, reducing reliance on centralized generation. Their ability to quickly adapt to local needs enhances overall system flexibility.

8. **Discuss the role of energy storage systems in power generation and distribution. What are the main types of energy storage technologies, and how do they contribute to balancing supply and demand? CO3**

Hint: Energy storage systems are crucial for balancing supply and demand, particularly with the increasing integration of renewable energy sources. They store excess energy during low demand periods and release it during peak demand, thus stabilizing the grid. Main types of energy storage technologies include battery systems (e.g., lithium-ion, lead-acid), pumped hydro storage, and compressed air energy storage. Each technology has unique characteristics regarding capacity, discharge time, efficiency, and application suitability, enabling diverse operational strategies to enhance grid reliability.

9. **Evaluate the differences between meshed and radial topologies in transmission and distribution systems. How do these configurations affect power flow, reliability, and maintenance practices? CO3**

Hint: Meshed topologies consist of multiple interconnected lines and nodes, allowing for multiple paths for power flow, which enhances reliability by providing alternatives in case of line failures. This configuration can better balance loads and manage voltage drops. In contrast, radial topologies feature a single source feeding multiple branches, which can lead to outages if one line fails, affecting reliability. Maintenance in meshed systems can be more complex due to the interconnected nature of the network, while radial systems may allow for easier isolation of faults. The choice of topology influences operational efficiency, resilience, and maintenance strategies in power systems.

10. **Critically assess the challenges faced by modern bulk power grids in integrating renewable energy sources. Discuss the technical, economic, and regulatory barriers, and propose potential solutions to enhance their adaptability. CO4**

Hint: Modern bulk power grids face several challenges when integrating renewable energy sources, including technical issues like grid stability and reliability due to the intermittent nature of sources like wind and solar. Economic barriers arise from the high initial investment costs for renewable technologies and infrastructure upgrades. Regulatory barriers can include outdated policies that do not facilitate the deployment of distributed energy resources (DERs) or incentivize traditional fossil fuel generation. Potential solutions to enhance adaptability include investing in advanced grid technologies (e.g., smart grids), implementing demand response programs to manage load fluctuations, establishing energy storage systems to balance supply and demand, and reforming regulatory frameworks to support renewable integration and decentralized energy production.

11. **Discuss the significance of the surge impedance and surge impedance loading in transmission lines. How do these concepts influence the design and operational strategies of power systems, particularly in terms of stability and efficiency? CO4**

Hint: Surge impedance is a key parameter in transmission lines, defined as $Z_0 = \sqrt{\frac{L}{C}}$, where L is inductance and C is capacitance. It represents the characteristic impedance of the line and plays a crucial role in determining how signals and power propagate through the system. Surge impedance loading (SIL) is the load at which the reactive power generated by the line's capacitance matches the reactive power consumed by the load, minimizing losses and ensuring efficient operation. These concepts influence the design of power systems by guiding the selection of line lengths, conductor configurations, and operating voltages. Proper management of surge impedance and SIL enhances system stability by preventing voltage instability and oscillations, thus improving the overall efficiency and reliability of power transmission, especially in long-distance lines and when integrating renewable energy sources.

Module 2:

1. Derive the formula for calculating voltage drop in a uniformly loaded DC distributor fed at one end. Include the assumptions made in the derivation.

2. Discuss the key differences between AC and DC distribution systems, including their advantages, limitations, and applications.

3. Derive the expression of voltage drop in a distributor feeding at one end for distributed loading.

4. Discuss about: i) Feeder ii) Distributor iii) Service mains

1. **What are the key differences between single-phase and three-phase AC distribution systems? Explain how each system affects load distribution and efficiency. CO1**

Hint: Single-phase AC distribution systems use a single alternating voltage waveform and are commonly used in residential applications. They are simpler but less efficient for high-power applications, as they can lead to voltage drops over long distances. Three-phase AC distribution systems use three alternating voltage waveforms, leading to more balanced load distribution and higher efficiency. This configuration allows for smaller conductor sizes, reduced losses, and the capability to power larger motors and industrial equipment more effectively.

2. **Describe the significance of a bus bar arrangement in electrical distribution systems. What are the advantages of using bus bars in substations? CO2**

Hint: A bus bar arrangement is crucial in electrical distribution systems as it serves as a common connection point for multiple circuits. It facilitates the distribution of electrical power to different feeders while ensuring system reliability and safety. Advantages of using bus bars in substations include reduced voltage drop, lower impedance, simplified maintenance and operation, and the ability to easily expand or modify the system. Bus bars also enhance fault tolerance by allowing for selective isolation of circuits during maintenance.

3. **What factors should be considered when selecting a site for a substation? Discuss at least three critical considerations. CO2**

Hint: When selecting a site for a substation, the following factors should be considered:

- **Proximity to Load Centers:** The substation should be located close to the main load centers to minimize transmission losses and ensure reliable power supply.
- **Environmental Impact:** The site should have minimal adverse effects on the surrounding environment, considering land use, wildlife, and local communities.
- **Accessibility and Safety:** The site must be easily accessible for maintenance and emergency operations, while also ensuring safety for both the public and the personnel working in the substation.

4. **Explain how voltage drop is calculated in an AC distribution system. What is the significance of considering power factor in these calculations? CO3**

Hint: Voltage drop in an AC distribution system is calculated using the formula $V_d = \frac{2 \times I \times R \times L}{1000}$, where V_d is the voltage drop, I is the load current, R is the resistance of the

conductor, and L is the one-way length of the conductor. The power factor (PF) is significant in these calculations as it affects the actual current drawn by the load. A low power factor increases the current, resulting in higher voltage drops, while a higher power factor indicates more efficient power use, reducing voltage drop and enhancing overall system performance.

5. **In a three-phase four-wire system, how is the neutral wire utilized, and what advantages does it provide in AC distribution? CO1**

Hint: In a three-phase four-wire system, the neutral wire is utilized to provide a return path for unbalanced loads. It helps stabilize the system voltage by allowing for the safe operation of single-phase loads connected between any phase and the neutral. Advantages of having a neutral wire include enhanced safety by preventing overvoltage conditions on single-phase loads, improved reliability by allowing the connection of varying loads without affecting system balance, and facilitating easier fault detection and isolation during disturbances.

1. **Explain the advantages of a three-phase system over a single-phase system in AC distribution. Include considerations of efficiency, power capacity, and load balancing in your response. CO4**

Hint: A three-phase system offers several advantages over a single-phase system, including:

- **Efficiency:** Three-phase systems can transmit more power with smaller conductors, leading to lower line losses.
- **Power Capacity:** They can deliver a higher amount of power, making them more suitable for industrial applications and large motors.
- **Load Balancing:** In three-phase systems, the power is more evenly distributed, reducing the likelihood of voltage fluctuations and improving overall system stability. The constant power delivery helps maintain a balanced load on the system, resulting in less wear on equipment and improved operational efficiency.

2. **Discuss the role of bus bar arrangements in substations. How do different configurations (e.g., single bus, double bus) affect the operational reliability and maintenance of the electrical distribution system? CO4**

Hint: Bus bar arrangements in substations play a critical role in distributing electrical power to various outgoing feeders. Different configurations have varying impacts on operational reliability and maintenance:

- **Single Bus:** This configuration is simpler and cost-effective but poses a risk of complete system shutdown during maintenance or fault conditions, as all outgoing circuits are connected to a single bus.
- **Double Bus:** This configuration allows for greater flexibility and reliability, as maintenance can be performed on one bus while the other remains operational, minimizing downtime. This arrangement enhances system reliability by providing redundancy, allowing for fault isolation without affecting the entire system.

3. **Describe the process and significance of voltage drop calculations in AC distributors. How does the power factor influence these calculations for different load conditions? CO3**

Hint: Voltage drop calculations in AC distributors are essential for ensuring that the voltage delivered to the end user remains within acceptable limits. The process involves calculating the voltage drop using the formula $V_d = \frac{2 \times I \times R \times L}{1000}$, considering the current (I), resistance (R), and length (L) of the conductor. The significance lies in preventing voltage drops that can lead to inefficient operation and equipment malfunction. The power factor influences these calculations because a lower power factor increases the current drawn by the load, resulting in a higher voltage drop. Thus, maintaining a high power factor is crucial for optimizing voltage levels and enhancing the efficiency of the distribution system.

4. **What factors should be considered when selecting a site for a substation? Discuss the implications of these factors on the reliability and efficiency of the power distribution system. CO3**

Hint: When selecting a site for a substation, several factors must be considered, including:

- **Proximity to Load Centers:** The site should be near major load centers to reduce transmission losses and improve response times.
- **Environmental Impact:** The environmental implications, such as land use, wildlife conservation, and community impact, must be assessed to mitigate negative effects.
- **Accessibility:** The site should be easily accessible for maintenance and emergency responses, ensuring operational reliability.
- **Safety Considerations:** The safety of the surrounding community and personnel must be prioritized to prevent accidents and ensure compliance with regulations. Considering these factors enhances the reliability and efficiency of the power distribution system by minimizing operational risks, ensuring timely maintenance, and optimizing power delivery to end users.

1. In a three-phase four-wire system, derive the expressions for voltage drop across each phase and the neutral wire. Discuss how different load conditions (balanced and unbalanced) affect this voltage drop calculations and the overall system performance. CO4

Hint: To derive the voltage drop expressions in a three-phase four-wire system, consider the following:

- For balanced loads, the voltage drop in each phase can be expressed as:

$$V_d = \frac{2 \times I \times R \times L}{1000}$$ (for each phase)

where I is the phase current, R is the resistance per phase, and L is the one-way length of the conductor.

- For unbalanced loads, the current in the neutral wire can be calculated as:

$$I_N = I_A + I_B + I_C$$

where I_A, I_B, and I_C are the phase currents. The voltage drop across the neutral can then be calculated using the same formula for each phase, considering that the current in the neutral wire can lead to a higher voltage drop, affecting the neutral point voltage.

Discussing the performance implications, balanced loads ensure uniform voltage drop across all phases, maintaining system stability. In contrast, unbalanced loads can lead to significant voltage differences between phases, resulting in inefficient operation, increased losses, and potential overheating of equipment.

2. Analyze the impact of different bus bar arrangements on the fault tolerance and operational efficiency of a power distribution system. Include a comparison of single bus, double bus, and ring bus configurations in your Hint. CO4

Hint: The choice of bus bar arrangement in a power distribution system significantly impacts fault tolerance and operational efficiency:

- **Single Bus Arrangement:** This configuration is cost-effective and simple but poses a high risk of complete system shutdown during maintenance or faults. All circuits are interconnected, making it vulnerable to outages if the bus fails.
- **Double Bus Arrangement:** This provides increased reliability, as it allows maintenance on one bus while keeping the other operational. It enhances fault tolerance because circuits can be reconfigured to isolate faults without interrupting the entire system, thus improving operational efficiency.
- **Ring Bus Arrangement:** This configuration offers redundancy and flexibility. If a fault occurs in one section, power can still flow through alternative paths. It balances the benefits of reliability and efficiency while minimizing the risk of total system failure.

In summary, while single bus arrangements are simpler and cheaper, double and ring bus configurations improve fault tolerance and operational efficiency, making them preferable in critical applications where reliability is essential.

Module 3:

1. What is load flow analysis? Classify various types of buses in a power system for load flow studies.

2. Write the advantages and disadvantages of Gauss –Seidal method and Newton Raphson method.

3. What is the Jacobian matrix in Newton-Raphson method?

What is acceleration factor in Gauss-Siedel method?

4. Derive static load flow equations for two bus system.

5. How can power flow analysis help in designing new power systems?

1. **Describe the basic structure of a power system. What are the main components involved, and what role does each component play in the overall operation of the system? CO1**

Hint: The basic structure of a power system consists of generation, transmission, and distribution components.

- **Generation:** This includes power plants that convert various forms of energy (thermal, hydro, solar, etc.) into electrical energy.
- **Transmission:** High-voltage transmission lines transport electricity over long distances to minimize losses. Substations step down the voltage for distribution.
- **Distribution:** This includes local networks that deliver electricity to end users. Distribution transformers reduce the voltage further for consumer use. Together, these components ensure the reliable delivery of electricity from generation sources to consumers.

2. **What is the Bus Admittance Matrix, and why is it important in power system analysis? CO2**

Hint: The Bus Admittance Matrix (Y-matrix) is a mathematical representation used in power system analysis to describe the relationship between the voltages and currents at different nodes (buses) in the system. Each element in the matrix represents the admittance (inverse of impedance) between buses. It is important because it simplifies the analysis of power flows, allowing for the application of numerical methods to solve for voltages and currents in the network, making it easier to assess system performance and stability.

3. **Define real power and reactive power. How do they balance at a node in a power system? CO1**

Hint:

- **Real Power (P):** This is the actual power consumed by electrical devices to perform work, measured in watts (W). It represents the energy that can be converted into useful work.
- **Reactive Power (Q):** This is the power that oscillates between the source and load, necessary for maintaining the voltage levels in the system, measured in reactive volt-amperes (VAR). At a node in a power system, the balance of real and reactive power is represented by the equations:

$$P_{in} - P_{out} = 0 \quad \text{and} \quad Q_{in} - Q_{out} = 0$$

This ensures that the total power supplied equals the total power consumed, maintaining system stability.

4. What are the Gauss-Seidel and Newton-Raphson methods, and how are they used in solving power flow equations? CO2

Hint:

- **Gauss-Seidel Method:** This is an iterative numerical method used to solve systems of linear equations. In power flow analysis, it updates the voltage estimates at each iteration based on the current power flow equations until convergence is achieved. It is simple but may converge slowly for large systems.
- **Newton-Raphson Method:** This method is also iterative but uses a Jacobian matrix to provide a more accurate and faster convergence. It is particularly effective for solving non-linear algebraic equations found in power flow analysis. The Newton-Raphson method is preferred for larger and more complex systems due to its faster convergence rate compared to Gauss-Seidel.

5. **Discuss some computational issues that may arise in large-scale power systems when performing power flow analysis. CO2**

Hint: Some computational issues in large-scale power systems include:

- **Convergence Problems:** Non-linear equations can lead to slow or non-convergence in iterative methods, particularly in systems with high levels of voltage instability or poor system conditions.
- **Computational Complexity:** As the size of the power system increases, the computational resources required for calculations (such as memory and processing time) can grow significantly, making real-time analysis challenging.
- **Numerical Instability:** Large matrices can lead to numerical instability, especially in methods that rely on matrix inversions, potentially causing inaccuracies in results.
- **Data Management:** Handling large volumes of data from numerous components in real-time can strain system performance and complicate data processing and analysis. Proper data organization and efficient algorithms are essential to mitigate these issues.

1. Explain the formation of the Bus Admittance Matrix (Y-matrix) in a power system. How does this matrix facilitate the analysis of power flows, and what are the key elements it contains? CO3

Hint: The Bus Admittance Matrix (Y-matrix) is formed by calculating the admittance between buses in a power system. Each element Y_{ij} represents the admittance between bus i and bus j. Diagonal elements (Yii) reflect the sum of the admittances connected to bus i, while off-diagonal elements (Yij) represent the negative admittance between buses i and j. This matrix facilitates power flow analysis by enabling the application of numerical methods to solve the load flow equations. By using the Y-matrix, one can derive voltage and current relationships efficiently, allowing for assessments of system stability and performance.

2. Derive the real and reactive power balance equations at a node in a power system. How do these equations help in maintaining system stability? CO3

Hint: The real and reactive power balance equations at a node can be expressed as:

$$P_{gen} - P_{load} - P_{loss} = 0$$

$$Q_{gen} - Q_{load} - Q_{loss} = 0$$

Where:

- P_{gen} and Q_{gen} are the generated real and reactive powers, respectively.
- P_{load} and Q_{load} are the consumed real and reactive powers, respectively.
- P_{loss} and Q_{loss} account for transmission losses.

These equations ensure that the power supplied equals the power consumed, which is essential for maintaining voltage levels and system stability. If the balance is disrupted, it can lead to voltage fluctuations, equipment stress, and potential system instability.

3. Compare and contrast the Gauss-Seidel and Newton-Raphson methods for solving power flow equations. Discuss the advantages and disadvantages of each method in the context of large-scale power systems. CO4

Hint:

- **Gauss-Seidel Method:**
  - **Advantages:** Simple to implement; requires less memory and computational resources; suitable for small systems.
  - **Disadvantages:** Convergence can be slow, especially for large systems or those with high power losses; may not converge at all for certain configurations.
- **Newton-Raphson Method:**
  - **Advantages:** Fast convergence, particularly for larger and more complex systems; provides better accuracy due to the use of a Jacobian matrix; can handle both voltage magnitude and angle.
  - **Disadvantages:** More complex to implement; requires significant computational resources and memory for large systems; may encounter numerical instability in poorly conditioned systems.

Overall, the choice of method depends on the system size, desired accuracy, and computational resources available.

4. Identify and explain three computational challenges in performing power flow analysis for large-scale power systems. How can these challenges be mitigated? CO4

Hint: Three computational challenges include:

Scalability Issues: As the size of the power system increases, the number of equations and variables grows, leading to longer computation times and higher memory usage. To mitigate this, one can use simplified models or decomposition techniques to break the system into smaller, more manageable parts.

Convergence Problems: Non-linearities in the power flow equations can lead to slow or non-convergence, particularly in systems with high levels of voltage instability. This can be addressed by using more robust algorithms (like modified Newton-Raphson) or applying techniques such as relaxation methods to improve convergence.

Data Management: Handling the vast amounts of data generated from large systems can strain computational resources. Implementing efficient data storage and retrieval systems, along with optimizing algorithms for data processing, can help manage this issue effectively. Additionally, using parallel processing techniques can enhance computational efficiency by distributing the workload across multiple processors.

1. Discuss the significance of the Jacobian matrix in the Newton-Raphson method for power flow analysis. Derive the expression for the Jacobian matrix used in the context of power flow equations and explain its role in achieving convergence. CO4

Hint: The Jacobian matrix in the Newton-Raphson method represents the partial derivatives of the power flow equations with respect to voltage magnitudes and angles. Its elements are derived from the power balance equations for both real (PPP) and reactive power (QQQ):

$$J = \begin{bmatrix} \frac{\partial P}{\partial V} & \frac{\partial P}{\partial \theta} \\ \frac{\partial Q}{\partial V} & \frac{\partial Q}{\partial \theta} \end{bmatrix}$$

Where:

- $\frac{\partial P}{\partial V}$ represents the sensitivity of real power with respect to voltage magnitudes.
- $\frac{\partial P}{\partial \theta}$ shows the sensitivity of real power with respect to voltage angles.
- $\frac{\partial Q}{\partial V}$ and $\frac{\partial Q}{\partial \theta}$ similarly represent the sensitivities for reactive power.

The Jacobian is critical in the iterative process of the Newton-Raphson method. It provides a linear approximation of the power flow equations around the current operating point, allowing the method to update voltage estimates more effectively. A well-conditioned Jacobian improves convergence speed, while poor conditioning can hinder the process or lead to divergence.

Module 4:

2. Derive the expression for the inductance of a 3-phase line without considering the effect of a transposition.

3. Draw the cross section of an insulated cable and explain the significance of the various layers.

4. (i) What is surge impedance?

(ii) Define surge impedance loading (SIL). What is its significance?

5. (i) What is the per-unit system?

(ii) What are the advantages of using the per unit system for power system?

6. (i) Define string efficiency in connection with suspension insulators.

(ii) State how with the help of guard rings string efficiency can be improved.

7. Explain various methods of improving string efficiency.

8. What is meant by "transposition of conductors"? Explain the necessity of transposition.

9. Derive the expression for the voltage regulation of a short transmission line for lagging power factor load.

10.What is Ferranti effect? Explain with phasor diagram.

11.What is corona?

How can the corona loss be minimized in a transmission line?

12. Prove that g max / g min in a single core cable is equal to D/d.

1. **Define the terms resistance, inductance, and capacitance in the context of overhead transmission lines. How do these parameters affect the performance of a transmission line? CO1**

Hint:

Resistance (R): It is the opposition to the flow of electric current in a conductor, affecting power losses due to heat dissipation. Higher resistance results in more energy loss.

Inductance (L): It is the property of a conductor that opposes changes in current. Inductance causes voltage drops and can affect reactive power flow in AC systems.

Capacitance (C): It is the ability of the transmission line to store electrical energy in an electric field. Capacitance can cause voltage rise and affect the charging current, especially in long lines.

These parameters impact the voltage regulation, power transfer capacity, and overall efficiency of transmission lines.

2. **Explain the concept of Geometric Mean Distance (GMD) and Geometric Mean Radius (GMR) in transmission line analysis. Why are these concepts important? CO2**

Hint:

Geometric Mean Distance (GMD): It is the average distance between multiple conductors in a transmission line, calculated by taking the geometric mean of the distances between the conductors.

Geometric Mean Radius (GMR): It is the effective radius of a conductor, calculated using the geometric mean of the radii of the individual conductors.

These concepts are important because they simplify the calculations of inductance and capacitance for multi-conductor transmission lines, allowing for more accurate modeling of electrical characteristics and performance.

3. **Differentiate between short, medium, and long transmission lines based on their length and the applicable models used for analysis. CO1**

Hint:

Short Transmission Lines: Typically less than 250 km, modeled using the RRR and XXX parameters only (series resistance and reactance). The C parameter is often neglected.

Medium Transmission Lines: Ranging from 250 km to about 500 km, modeled using the ABCD parameters, which include both series and shunt elements (taking into account the capacitance).

Long Transmission Lines: Greater than 500 km, requiring a more detailed model that includes the effects of line capacitance and uses distributed parameter models. These lines consider both series and shunt capacitance, leading to complex calculations of voltage regulation and power transfer.

4. **What is the Ferranti effect in transmission lines? Under what conditions does it occur, and what are its implications for power system operation? CO2**

Hint: The Ferranti effect refers to the phenomenon where the voltage at the receiving end of a long transmission line is higher than the voltage at the sending end when the line is lightly loaded or unloaded.

Conditions:

- It typically occurs in long transmission lines due to the capacitive effects of the line. The capacitance can cause the line to absorb reactive power, leading to a voltage rise at the receiving end.

Implications:

- This effect can lead to voltage regulation issues, causing equipment at the receiving end to experience higher voltages than rated levels, potentially leading to damage or operational failures. It necessitates the use of voltage regulation devices to maintain system stability.

5. **Describe the various types of insulators used in overhead transmission lines. How is the voltage distribution across a suspension insulator string determined? CO1**

Hint:

- **Types of Insulators**:
    - **Pin Insulators**: Used in low-voltage lines, mounted on pins.
    - **Suspension Insulators**: Used for high-voltage lines, hung from a supporting structure.

- **Strain Insulators**: Used where there are changes in direction or elevation in the line.

Voltage Distribution:

- In a suspension insulator string, the voltage is not uniformly distributed across each insulator. The voltage across each insulator can be determined using the formula:

$$V_i = \frac{V}{n} \cdot (\text{string efficiency})$$

where V is the total voltage across the string, and n is the number of insulators. The lower insulators carry more voltage due to unequal distribution caused by the tension in the string. The voltage distribution can also be analyzed using a simple series circuit approach, factoring in the string efficiency and the insulator's individual capacitances.

1. **Explain the concept of Surge Impedance and Surge Impedance Loading (SIL) in transmission lines. How do they affect the performance of overhead transmission lines? CO3**

Hint: Surge Impedance is the characteristic impedance of a transmission line when it is considered as a transmission medium for electromagnetic waves. It is determined by the ratio of the line's inductance (L) to its capacitance (C):

$$Z_0 = \sqrt{\frac{L}{C}}$$

Surge Impedance Loading (SIL) is the load at which the reactive power generated by the line capacitance exactly matches the reactive power consumed by the line's inductance, allowing for optimal power transfer without voltage rise or drop.

Effects:

- When the load is at SIL, the voltage remains stable; deviations from this point can lead to voltage regulation issues.
- If the load is lower than SIL, the line may operate in a capacitive mode, resulting in a voltage rise (Ferranti effect).
- If higher, it may operate in an inductive mode, causing a voltage drop.

2. **Discuss the importance of the ABCD parameters in the analysis of transmission lines. Derive the expressions for these parameters for a medium transmission line. CO4**

Hint: The ABCD parameters are crucial in the analysis of medium transmission lines, representing the relationship between the sending end voltage and current and the receiving end voltage and current. The parameters are defined as follows:

- A: Voltage regulation factor (dimensionless)
- B: Reactance of the line (Ohms)
- C: Admittance of the line (Siemens)

- D: Current regulation factor (dimensionless)

Derivation: For a medium transmission line:

$$V_s = AV_r + BI_r$$

$$I_s = CV_r + DI_r$$

The exact derivation involves considering the line's series resistance and reactance and shunt capacitance, resulting in:

- A=D=1 (for short lines)
- B=Z_{line}
- $C = Y_{line}/2$ (considering half for both ends) The ABCD parameters allow for simplified calculations of voltage drop and power flow in the line.

3. **What is the role of voltage distribution in a suspension insulator string? Describe how to calculate the string efficiency and the factors affecting it. CO2**

Hint: Voltage distribution in a suspension insulator string is critical because it determines how voltage is shared among the insulators. The lower insulators typically experience higher voltages due to their position in the string, which can lead to insulation failure if not properly managed.

String Efficiency Calculation: String efficiency is defined as the ratio of the voltage across the entire string to the sum of the voltages across each insulator:

$$\text{String Efficiency} = \frac{\text{Total Voltage across string}}{\text{Sum of voltages across insulators}} \times 100\%$$

Factors affecting string efficiency include:

- Unequal distribution of voltage due to differences in insulator capacitance.
- The number of insulators in the string.
- The physical configuration of the insulators and the line.

4. **Describe the concept of the Ferranti effect and its significance in the operation of long transmission lines. How can this effect be mitigated in practical applications? CO4**

Hint: The Ferranti effect occurs when the voltage at the receiving end of a long transmission line exceeds the voltage at the sending end, typically when the line is lightly loaded or unloaded. This effect is mainly due to the capacitive nature of long transmission lines, which causes them to absorb reactive power and increase voltage levels.

Significance:

- It can lead to overvoltage conditions at the receiving end, posing risks to equipment and system stability.

- Understanding this effect is crucial for proper system design, especially in long-distance transmission systems.

Mitigation Strategies:

- **Shunt Reactors**: Placing shunt reactors at the receiving end to absorb excess reactive power.
- **Voltage Regulation Equipment**: Using voltage regulators and transformers to control voltage levels dynamically.
- **Load Management**: Ensuring adequate loading on the line to minimize the occurrence of the Ferranti effect.

1. **Derive the equations for the resistance, inductance, and capacitance per unit length for a two-wire transmission line. Explain how these parameters influence the overall performance of the transmission line, especially in terms of power loss and voltage regulation. CO2**

Hint:

- **Resistance (R)**: The resistance per unit length for a two-wire line is given by:

$$R = \frac{\rho}{A}$$

where ρ is the resistivity of the conductor material and A is the cross-sectional area. Resistance causes power losses in the form of heat, calculated using $P = I^2R$.

- **Inductance (L)**: The inductance per unit length of a two-wire line can be derived using the formula:

$$L = \frac{\mu}{\pi} \ln\left(\frac{D}{r}\right)$$

where μ is the permeability of the medium, D is the distance between the conductors, and r is the radius of the conductors. Higher inductance results in increased reactance, affecting the voltage drop and reactive power flow.

- **Capacitance (C)**: The capacitance per unit length is given by:

$$C = \frac{2\pi\epsilon}{\ln\left(\frac{D}{r}\right)}$$

where ϵ is the permittivity of the medium. Capacitance influences the charging current and voltage profile, especially in long transmission lines.

Influence on Performance:

- High resistance leads to significant power losses and affects voltage regulation negatively.

- Increased inductance can cause reactive power issues and voltage drops during load variations.
- High capacitance enhances voltage rise in long lines, leading to the Ferranti effect if not properly managed.

2. **Explain the calculation of sag in overhead transmission lines and discuss its significance in line design. How does the choice of insulator type affect sag calculations? CO2**

Hint:

- **Sag Calculation**: The sag (SSS) in an overhead transmission line can be calculated using the parabolic approximation for a uniformly loaded line:

$$S = \frac{wL^2}{8T}$$

where w is the weight of the conductor per unit length, L is the span length, and T is the horizontal tension in the conductor. This equation assumes that the load is evenly distributed along the line.

- **Significance in Line Design**:
  - Sag affects the clearance between the conductor and the ground or objects below, which is crucial for safety and operational efficiency.
  - Proper sag calculation ensures that the line maintains a stable position under various loading conditions, preventing excessive tension and potential failure.
- **Effect of Insulator Type**:
  - Different types of insulators (pin, suspension, strain) can influence the effective height at which the conductor is mounted and the tension in the line.
  - Suspension insulators, commonly used for high voltage lines, allow more flexibility in sag calculations due to their ability to accommodate changes in tension without transferring excessive load to the tower.
  - The insulator type can also affect the overall weight supported, influencing the tension and, subsequently, the sag in the line. Proper consideration of these factors is vital for ensuring that the line design meets the required mechanical and electrical performance criteria.

10 Marks Long question

Module 1:

1. (i) With neat sketch, explain typical micro grid configuration.
   (ii) What is the role of distributed energy resources?

2. (i) Draw and explain the structure of power system indicating the voltage level in each transmission line.
   (ii) Why is electric power preferably to be transmitted at a high voltage?
3. (i) Discuss and compare Radial and Ring main distribution system.
   (ii) What is the role of interconnectors in distribution systems?

1. Describe the evolution of power systems from the early days of electricity generation to the present-day scenario. Highlight key developments in technology and policy that have shaped modern power systems. CO1

Hint:

- Early power systems were localized and based on direct current (DC) generation, primarily for lighting.
- The transition to alternating current (AC) systems allowed for long-distance transmission, leading to the establishment of larger power grids.
- The introduction of transformers enhanced voltage levels, improving efficiency and enabling the creation of bulk power systems.
- Regulatory frameworks evolved, leading to unbundling of generation, transmission, and distribution sectors, promoting competition.
- Recent developments include the integration of renewable energy sources (solar, wind), smart grid technologies, and distributed energy resources (DERs), driven by the need for sustainability and energy independence.

2. Compare and contrast bulk power grids and micro-grids. Discuss their respective advantages and disadvantages in terms of reliability, scalability, and integration of renewable energy sources. CO2

Hint:

- Bulk Power Grids:
  - Advantages:
    - High capacity for energy transmission over long distances.
    - Economies of scale in generation and distribution.
    - Ability to integrate a diverse mix of energy sources, including renewables.
  - Disadvantages:
    - Vulnerable to widespread outages.
    - High initial infrastructure costs.
    - Difficulty in managing demand response due to large-scale operations.
- Micro-Grids:

- Advantages:
    - Enhanced reliability and resilience, especially in isolated areas.
    - Local energy generation and consumption, reducing transmission losses.
    - Easier integration of renewable energy sources (solar, wind).
- Disadvantages:
    - Higher costs for small-scale generation technologies.
    - Challenges in coordination and control when operating in conjunction with bulk power grids.
    - Limited capacity compared to bulk systems.

Moderate-Level Questions

1. **Question: Explain the concept of distributed energy resources (DERs) and their impact on the modern power system. Include examples of different types of DERs and discuss the challenges and benefits of integrating them into the existing grid infrastructure. CO3**

Hint:

- Definition: Distributed Energy Resources (DERs) refer to small-scale energy generation or storage technologies located close to the point of consumption. Examples include solar panels, wind turbines, battery storage, and combined heat and power (CHP) systems.
- Impact on Power Systems:
    - Increased resilience and reliability of the energy supply.
    - Reduction in transmission losses due to localized generation.
    - Contribution to energy independence and sustainability.
- Challenges:
    - Integration issues with the existing grid infrastructure.
    - Variability and intermittency of renewable sources leading to stability concerns.
    - Need for advanced grid management technologies to handle distributed generation.
- Benefits:
    - Enhanced flexibility in energy management and consumption.
    - Potential for reduced energy costs for consumers.

- Opportunities for community engagement in energy production and consumption.

2. **Discuss the various energy storage technologies available for power systems today. Analyze how energy storage can enhance the stability and reliability of the grid, particularly in relation to renewable energy integration. CO4**

Hint:

- Energy Storage Technologies:
  - Batteries: Lithium-ion, lead-acid, and flow batteries provide quick response times and are suitable for balancing short-term fluctuations.
  - Pumped Hydro Storage: Utilizes excess energy to pump water uphill, which can be released to generate electricity when needed.
  - Flywheels: Store kinetic energy and provide rapid bursts of power, enhancing grid stability.
  - Compressed Air Energy Storage (CAES): Stores energy in the form of compressed air in underground caverns, releasing it to generate power.
- Enhancements to Grid Stability:
  - Energy storage helps to manage the variability of renewable energy sources by storing excess generation and releasing it during peak demand periods.
  - Provides frequency regulation and voltage support, improving overall grid reliability.
  - Enables the implementation of demand response strategies, shifting energy consumption to off-peak times.
- Conclusion: By effectively integrating energy storage technologies, power systems can achieve higher penetration of renewable energy sources while maintaining stability, reliability, and efficiency in operations.

Module 2:

1. i) A 2-wire d.c. street mains AB, 600 m long is fed from both ends at 220 V. Loads of 20 A, 40 A, 50 A and 30 A are tapped at distances of 100m, 250m, 400m and 500 m from the end A respectively. If the area of X-section of distributor conductor is 1cm2, find the minimum consumer voltage. Take $\rho = 1•7 \times 10- 6\ \Omega$ cm. [CO3]

ii)Describe the main differences between radial, ring, and interconnected distribution systems.

1. **Explain the differences between single-phase and three-phase AC distribution systems. Discuss the advantages of using a three-phase system over a single-phase system for power distribution. CO1**

Hint:

- Single-Phase System: Generally used for small-scale, residential power distribution. It consists of a single alternating current, which is less efficient for transmitting large amounts of power.
- Three-Phase System: Used for industrial and large-scale power distribution, consisting of three alternating currents that are 120° out of phase with each other.
- Advantages of Three-Phase Over Single-Phase:
  - More efficient power transmission and lower power loss.
  - Ability to deliver higher power levels with less conductor material.
  - Provides a smoother and more consistent power flow, ideal for running heavy machinery.

2. **Describe the basic bus bar arrangements used in substations. What factors determine the selection of a specific bus bar configuration? CO2**

Hint:

- Types of Bus Bar Arrangements:
  - Single Bus Bar System
  - Double Bus Bar System
  - Main and Transfer Bus System
  - Ring Bus System
- Factors for Selection:
  - Reliability requirements
  - Cost constraints
  - Maintenance needs
  - Operational flexibility

1. **Discuss the factors to consider when selecting a site for a substation. Explain how geographical location, environmental impact, and load distribution influence the choice. CO3**

Hint:

- Key Factors:
  - Proximity to Load Centers: Reduces transmission losses and improves voltage regulation.
  - Geographical Location: Accessibility, topography, and land availability.
  - Environmental Impact: Minimizing effects on the local environment and adherence to regulations.

        - Connectivity: Easy access to existing transmission lines and grid infrastructure.
    - Influences:
        - Load distribution directly affects where the substation should be placed to ensure efficient power delivery.
        - The geographical layout may determine the cost and complexity of constructing the substation.

2. **Explain the concept of a 3-phase 4-wire distribution system. What are its applications, and why is it commonly used in residential areas? CO2**

Hint:

- Concept:
    - A 3-phase 4-wire system consists of three phase conductors and a neutral wire. The neutral allows for both single-phase and three-phase loads to be connected, making it versatile for mixed usage.
- Applications:
    - Commonly used in residential, commercial, and industrial settings where a combination of single-phase and three-phase equipment is utilized.
- Reason for Use in Residential Areas:
    - Allows for efficient delivery of power to homes, supporting standard household appliances (single-phase) while also accommodating higher power requirements (three-phase).

1. **Derive the formula for voltage drop in an AC distributor when the power factor is referred to the receiving end voltage. Explain how this calculation differs when the power factor is with respect to the load voltages. Include the impact of these factors on overall system performance. CO4**

Hint:

- Voltage Drop Calculation:
    - Voltage drop ΔV in an AC distributor can be expressed as: $\Delta V = IR\cos\phi + IX\sin\phi$
    - where I is the current, R is the resistance, X is the reactance, and ϕ is the phase angle (power factor).
- Differences Based on Power Factor Reference:
    - When power factor is referred to the receiving end voltage, it involves calculating the voltage drop from the receiving end towards the supply.

        - If referred to the load voltage, calculations consider the point of load connection and may result in different phase angles.
    - Impact on System Performance:
        - Accurate voltage drop calculations are essential for maintaining system stability and ensuring appropriate voltage levels at various points in the network.

2. **Given a practical numerical problem, calculate the voltage drop in an AC distributor for a specific case where power factors differ at two loads connected along the line. Analyze the effects of power factor variation on the voltage regulation and overall efficiency of the distribution system. CO3**

Example Problem:

- A 2-wire AC distributor has a length of 200m with two loads connected at 100m and 200m from the supply point. The load at 100m draws 10A at a power factor of 0.8 lagging, while the load at 200m draws 15A at a power factor of 0.9 lagging. The resistance of the line is 0.05 ohms per 100m, and the reactance is 0.04 ohms per 100m.

Solution Steps:

- Determine the individual voltage drops caused by each load.
- Calculate the total voltage drop across the distributor.
- Analyze how the varying power factors affect the voltage regulation.
- Conclusion: Power factor plays a significant role in determining voltage drops. Lower power factors lead to higher drops, affecting voltage regulation and system efficiency.

Module 3:

1. Explain Gauss-Seidel iterative method for power flow analysis of any given power system with a flow chart.

2. Describe the real and reactive power balance equations at a node in a power system. How are these equations used in power flow analysis?

3.The parameters of a 4-bus system are as under:

Bus Code	Line impedance(pu)	charging admittance(pu)
1-2	0.2+j0.8	j0.02
2-3	0.3+j0.9	j0.03
2-4	0.2+j1.0	j0.04
3-4	0.2+j0.8	j0.02

1-3	0.1+j0.4	j0.01

Draw the network and find the admittance matrix

4. Distinguish between voltage control bus and swing bus. What do you mean by Jacobian Matrix? Discuss the NR method of solving SLFE [3+3+4]

5.Explain the necessity of load flow studies in power system. Derive static load flow equations for two bus system.

1. **Explain the basic structure of a power system. What are its main components, and how do they function together to deliver electricity from generation to consumers? CO1**

Hint:

- Components:
  - Generation: Produces electricity using various energy sources (thermal, hydro, nuclear, renewable).
  - Transmission: High-voltage lines transport electricity over long distances.
  - Distribution: Lowers the voltage and delivers electricity to consumers.
  - Consumers: End users of electricity (residential, commercial, industrial).
- Functioning Together: Electricity generated at power plants is transmitted through high-voltage lines to substations, where it is stepped down to lower voltages and distributed to consumers.

2. **What is the purpose of the Bus Admittance Matrix (Y-bus) in power system analysis? How is it formed? CO2**

Hint:

- Purpose: The Y-bus matrix represents the admittances between buses (nodes) in a power system. It is essential for power flow analysis, fault analysis, and stability studies.
- Formation: It is created using the network topology and line impedances. Each element represents the admittance between two buses or the self-admittance of a bus.

3. **Describe the difference between real power and reactive power in a power system. Why is it important to balance both at a node? CO2**

Hint:

- Real Power (P): The actual power that performs work (measured in watts).
- Reactive Power (Q): The power that oscillates between the source and load (measured in volt-amperes reactive, VAR).
- Importance of Balance: Balancing both ensures system stability, efficient operation, and maintains appropriate voltage levels across the system.

4. **What are the typical specifications required for defining a load and a generator in power flow studies? CO1**

Hint:

- Load Specifications: Active power (P), reactive power (Q), voltage magnitude, and connection point.
- Generator Specifications: Active power output, reactive power limits, voltage setpoint, and bus type (e.g., PV bus, slack bus).

1. **Explain the Gauss-Seidel method for solving power flow equations. What are its advantages and disadvantages compared to other numerical methods? CO4**

Hint:

- Gauss-Seidel Method: Iterative method that updates bus voltages one at a time, using initial estimates and continuing until convergence.
- Advantages: Simple to implement and computationally efficient for smaller systems.
- Disadvantages: Slow convergence for large systems, may fail to converge if the initial guess is poor or the system is not well-conditioned.

2. **How do computational issues in large-scale power systems affect power flow analysis? Discuss the challenges and possible solutions to these issues. CO3**

Hint:

- Challenges:
  - Size and Complexity: Large systems have numerous buses and lines, leading to massive Y-bus matrices.
  - Convergence Issues: More iterations are required, increasing computational time.
  - Data Management: Handling large datasets and ensuring accurate modeling.
- Solutions: Use of efficient numerical methods (e.g., Newton-Raphson), parallel computing, and advanced data handling techniques.

1. **Derive the power flow equations for a simple 2-bus system, and explain how the Newton-Raphson method can be applied to solve these equations. Discuss why**

Newton-Raphson is often preferred over Gauss-Seidel for large-scale systems. CO4

Hint:

- Derivation:
  - Define real and reactive power equations based on bus voltages, admittances, and angles.
  - Express equations in terms of P and Q, forming a set of non-linear algebraic equations.
- Newton-Raphson Application:
  - Linearize the non-linear equations using Taylor series expansion.
  - Use Jacobian matrix to iteratively update the voltage magnitudes and angles until convergence.
- Preference Reason: Faster convergence, especially for large, complex systems; handles ill-conditioned problems more effectively.

2. **Discuss the impact of system scaling on the formation of the Bus Admittance Matrix (Y-bus) and its computational requirements. How can modern computational techniques help address these challenges in real-time power system operations? CO3**

Hint:

- Impact of Scaling:
  - Larger systems lead to larger matrices, increasing storage requirements and computational time.
  - Sparse nature of Y-bus matrices means many elements are zero, necessitating efficient storage and manipulation techniques.
- Modern Computational Techniques:
  - Sparse Matrix Techniques: Reduce memory usage and speed up computations by only storing non-zero elements.
  - Parallel Computing: Distribute computations across multiple processors to handle real-time operations effectively.
  - Advanced Algorithms: Use faster, iterative algorithms (e.g., Fast Decoupled Load Flow) for quicker convergence.

Module 4:

1. (i) How is transmission lines classified?
   (ii) Define regulation of a transmission line.
   (iii) Derive the A, B, C, D parameters for long transmission line.
2. (i) Explain various methods of improving string efficiency.

(ii) In a 33 kV overhead line, there are three units in the string of insulators. If the capacitance between each insulator pin and earth is 11% of the self-capacitance of each insulator. Find String Efficiency.

3. (i) Draw and explain underground cable cross section diagram.
   (ii) Prove that g max / g min in a single core cable is equal to D/d.
4. (i) Why transposition is required in a transmission line?
   (ii) A single-phase transmission line consists of two parallel conductors one meter apart and 1.25 cm in diameter. Calculate the loop inductance per km of the line.
5. (i) What is surge impedance loading? What is Reactive Power?
   (ii) Show that the inductance per loop meter of a two-wire transmission line using solid round conductor is given by
   is given by

$$L = 4 \times 10^{-7} \ln \frac{d}{r'} \quad \text{H},$$

Where, d is the distance between the conductors and r' is the GMR of the conductors.

6. i)What do you mean by tariff? Describe the desirable characteristics of a tariff.
   ii)What is sag in overhead lines? What factors affects sag?

1. **Explain the difference between short, medium, and long transmission lines. How are their electrical characteristics typically analyzed? CO2**

Hint:

- Short Lines: Less than 80 km, consider only resistance and inductance.
- Medium Lines: 80-250 km, include resistance, inductance, and capacitance; represented using nominal-π or T model.
- Long Lines: More than 250 km, require distributed parameter analysis; modeled using exact transmission line equations.

2. **What is the concept of Ground Mutual Distance (GMD) and Ground Mutual Radius (GMR) in transmission line analysis? Why are they important? CO1**

Hint:

- GMD: Average distance between conductors, affects line inductance.
- GMR: Equivalent radius for calculating self-inductance of a conductor.
- Importance: Accurate calculation of inductance and capacitance for efficient transmission line design.

3. **Describe the basic structure of a suspension insulator and explain the concept of string efficiency. CO2**

Hint:

- Structure: Series of disk insulators connected to form a string, supporting transmission lines.
- String Efficiency: Ratio of voltage across the entire string to the product of the number of insulators and the voltage across the bottom insulator. Higher efficiency means better voltage distribution.

4. **What are ABCD constants in transmission lines, and how do they relate to the parameters of a transmission network? CO3**

Hint:

- ABCD Constants: Parameters that relate sending end voltage/current to receiving end voltage/current in a transmission line.
- Relation: Help in understanding the behavior of the line under different loading conditions; essential for network analysis.

5. **Explain the phenomenon of corona discharge in transmission lines. What are its causes and effects? CO4**

Hint:

- Phenomenon: Ionization of air around conductors when voltage exceeds a certain threshold, causing a visible glow.
- Causes: High voltage, small conductor size, and proximity of conductors.
- Effects: Power loss, noise, and radio interference.

1. **How is the inductance of a two-wire transmission line calculated? Discuss the effects of conductor spacing and arrangement on the inductance. CO3**

Hint:

- Inductance Calculation: Using self and mutual inductance formulas, incorporating GMD and GMR.
- Effects of Spacing: Greater spacing reduces mutual inductance, lowering overall inductance. Arrangement (transposed or un-transposed) affects inductance balance.

2. **Describe the Ferranti effect in transmission lines. How does it impact long transmission lines, and what measures can be taken to mitigate it? CO4**

Hint:

- Ferranti Effect: Increase in voltage at the receiving end compared to the sending end during light loading or no load, due to line capacitance.
- Impact: Overvoltage can damage equipment and affect stability.
- Mitigation: Use of shunt reactors or line compensation.

3. **Discuss the parameters and grading of underground cables. What makes them different from overhead transmission lines? CO2**

Hint:

- Parameters: Resistance, capacitance, inductance, and dielectric losses.
- Grading: Use of different insulation layers to manage stress distribution and enhance performance.
- Difference: Underground cables have lower inductance but higher capacitance; no visual obstruction, less affected by weather, but more expensive and harder to repair.

4. **Explain the per-unit system in power systems. How does it simplify calculations in transmission and distribution networks? CO1**

Hint:

- Per-Unit System: Normalizes electrical quantities to a common base value (voltage, power, impedance).
- Simplification: Easier comparison and calculation across different system components by eliminating the need to convert between units; simplifies complex network analysis.

1. **Derive the expression for the ABCD constants of a medium-length transmission line using the nominal-π model. Explain how each constant affects the overall power transfer capability of the line. CO4**

Hint:

- Derivation:
  - Define the nominal-π model with series impedance (Z) and shunt admittance (Y/2) at both ends.
  - Express sending end voltage/current in terms of receiving end quantities, leading to the ABCD matrix.
- Effect on Power Transfer:
  - A, D: Determine voltage regulation.
  - B: Represents series impedance, affecting power loss.
  - C: Represents shunt admittance, impacting line charging.

2. **Discuss the calculation of sag in overhead transmission lines. Derive the formula for sag when supports are at equal and unequal levels. What are the practical considerations for designing transmission line sag? CO3**

Hint:

- Sag Calculation:
  - For equal supports: $S = \frac{WL^2}{8T}$

- (where W is weight per unit length, L is span length, T is tension).
- For unequal supports: More complex, involving horizontal and vertical distances.

- Practical Considerations:
  - Ensure safety clearance, account for temperature variations, wind pressure, and ice loading; proper sag maintains line stability and minimizes stress on conductors.